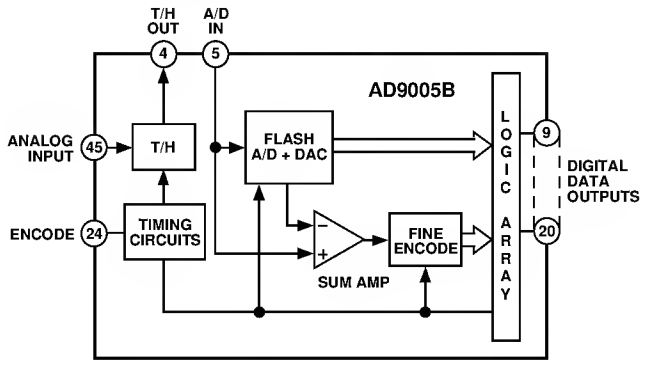
# 12-Bit, 10 MSPS A/D Converter

# AD9005B

**FEATURES**
- Complete 12-Bit A/D Converter
- Includes Track-and-Hold, Reference and Timing
- Bipolar Analog Input (±1.024 V)
- Up to 10 MSPS Sampling Rate
- Low Power Dissipation: 3.2 W
- Low Harmonic Distortion
- MIL-STD-883-Compliant Versions Available

**APPLICATIONS**
- Radar
- Digital Receivers
- Electro-Optics
- Medical Scanners
- Signal Intelligence
- Spectrum Analyzers

**FUNCTIONAL BLOCK DIAGRAM**




## GENERAL DESCRIPTION

The AD9005B is a complete 12-bit A/D converter that includes on-board track-and-hold amplifier, voltage reference, and timing circuits. Featuring sampling rates from dc to 10 MSPS, the AD9005B uses a subranging converter architecture to achieve high speed and high resolution. Dynamic performance includes an SNR of 64 dB and harmonic distortion of –72 dBc with a 4.3 MHz analog input.

This unit replaces its predecessor, the AD9005A. The AD9005B uses a higher level of integration than the earlier design to provide increased performance, better reliability and reduced cost.

The AD9005B requires only +5 V and –5.2 V supplies (eliminating the +15 V and –15 V requirements of the AD9005A). The AD9005B will operate without board modification in AD9005A sockets because +15 V and –15 V pins are not internally connected. All grades are fully tested for dynamic performance.

Critical to the performance of the AD9005B is the use of advanced bipolar integrated circuits, custom designed for this device and manufactured by Analog Devices. The AD9005B is TTL-compatible with offset binary outputs. It is available in a 46-lead hermetic metal DIP in two temperature ranges: 0°C to +70°C commercial range and –55°C to +125°C military range (case temperature).

REV. 0



One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 617/329-4700 World Wide Web Site: http://www.analog.com
Fax: 617/326-8703

# AD9005B–SPECIFICATIONS

**ABSOLUTE MAXIMUM RATINGS**[1]

Positive Supply Voltage ($+V_S$) . . . . . +6 V
Negative Supply Voltage ($-V_S$) . . . . . –6 V
Analog Input Voltage (Pin 45) . . . . . ±3.0 V dc
Digital Input Voltage . . . . . –0.5 V to $+V_S$
Digital Output Current . . . . . 4 mA

Operating Temperature Range (Case)
AD9005BKM . . . . . 0°C to +70°C
AD9005BTM . . . . . –55°C to +125°C
Storage Temperature Range . . . . . –65°C to +150°C
Junction Temperature[2] . . . . . +175°C
Lead Soldering Temperature (10 sec) . . . . . +300°C

## ELECTRICAL CHARACTERISTICS ($+V_S$ = +5 V, $-V_S$ = –5.2 V, unless otherwise noted)

| Parameter | Temp | Test Level | Commercial 0°C to +70°C AD9005BKM Min | Typ | Max | Military –55°C to +125°C AD90005BTM/KJ Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|---|---|
| RESOLUTION | +25°C | I | 12 | | | 12 | | | Bits |
| LSB Weight | Full | V | | 0.5 | | | 0.5 | | mV |
| STATIC ACCURACY | | | | | | | | | |
| Differential Nonlinearity | +25°C | I | –1.0 | ±0.5 | +1.0 | –1.0 | ±0.5 | +1.0 | LSB |
| | Full | VI | –1.0 | | +1.5 | –1.0 | | +1.5 | LSB |
| Integral Nonlinearity | +25°C | I | | ±1.0 | ±1.25 | | ±1.0 | ±1.25 | LSB |
| | Full | IV | | | ±2.25 | | | ±2.25 | LSB |
| No Missing Codes | Full | VI | GUARANTEED | | | GUARANTEED | | | |
| Gain Error | +25°C | I | | ±0.5 | ±1.0 | | ±0.5 | ±1.0 | % FS |
| | Full | VI | | | ±2.0 | | | ±2.0 | % FS |
| Offset Error | +25°C | I | | ±4 | ±15 | | ±4 | ±15 | mV |
| | Full | VI | | | ±30 | | | ±40 | mV |
| ANALOG INPUT | | | | | | | | | |
| Input Voltage Range | Full | V | | ±1.024 | | | ±1.024 | | V p-p |
| Input Resistance | Full | VI | 900 | 1000 | 1100 | 900 | 1000 | 1100 | Ω |
| Input Capacitance | +25°C | V | | 8 | | | 8 | | pF |
| Large Signal Input Bandwidth[3] | Full | V | | 38 | | | 38 | | MHz |
| DYNAMIC CHARACTERISTICS[5] | | | | | | | | | |
| Maximum Conversion Rate | Full | I | 10 | | | 10 | | | MSPS |
| Output Data Delay[6, 9] ($t_{PD}$) | +25°C | V | | 90 | | | 90 | | ns |
| Aperture Delay ($t_A$) | +25°C | V | | 9 | | | 9 | | ns |
| Aperture Uncertainty | +25°C | IV | | 10 | 20 | | 10 | 20 | ps rms |
| Transient Response (to ±1 LSB)[7] | +25°C | IV | | | 120 | | | 120 | ns |
| Overvoltage Recovery Time[8] (to ±1 LSB) | +25°C | IV | | | 250 | | | 250 | ns |
| Harmonic Distortion[10, 4] | | | | | | | | | |
| $F_{IN}$ = 540 kHz | + 25°C | IV | –73 | –78 | | –73 | –78 | | dBc |
| $F_{IN}$ = 2.3 MHz | +25°C | I | –68 | –72 | | –68 | –72 | | dBc |
| | Full | VI | –67 | | | –66 | | | dBc |
| $F_{IN}$ = 4.3 MHz | +25°C | I | –66 | –72 | | –66 | –72 | | dBc |
| | Full | VI | –65 | | | –63 | | | dBc |
| Signal to Noise Ratio[11, 4] | | | | | | | | | |
| $F_{IN}$ = 540 kHz | +25°C | IV | 65 | 67 | | 65 | 67 | | |
| $F_{IN}$ = 2.3 MHz | +25°C | I | 63 | 65 | | 63 | 65 | | dB |
| | Full | VI | 63 | | | 60 | | | dB |
| $F_{IN}$ = 4.3 MHz | +25°C | I | 62 | 64 | | 62 | 64 | | dB |
| | Full | VI | 61 | | | 60 | | | dB |
| Two-Tone Intermodulation Distortion[12] | | | | | | | | | |
| $F_{IN}$ = 2.2 MHz + 2.3 MHz | +25°C | V | | –75 | | | –75 | | dBc |
| ENCODE INPUT[14] | | | | | | | | | |
| Logic "1" Voltage | Full | IV | 2.0 | | | 2.0 | | | V |
| Logic "0" Voltage | Full | IV | | | 0.8 | | | 0.8 | V |
| Logic "1" Current | Full | I | | | 150 | | | 150 | µA |
| Logic "0" Current | Full | I | | | 150 | | | 150 | µA |
| Input Capacitance | +25°C | V | | 5 | | | 5 | | pF |
| Encode Pulse Width (High) | +25°C | IV | 25 | | | 25 | | | ns |

| Parameter | Temp | Test Level | Commercial 0°C to +70°C AD9005BKM Min | Typ | Max | Military −55°C to +125°C AD9005BTM Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|---|---|
| DIGITAL OUTPUTS | | | | | | | | | |
| Logic "1" Voltage (2 mA Source) | Full | I | 2.4 | | | 2.4 | | | V |
| Logic "0" Voltage (4 mA Sink) | Full | I | | | 0.4 | | | 0.4 | V |
| Logic Coding | Full | IV | | Offset Binary | | | Offset Binary | | |
| POWER SUPPLY | | | | | | | | | |
| Supply Voltage $+V_S$ | Full | VI | 4.75 | 5.0 | 5.25 | 4.75 | 5.0 | 5.25 | V |
| Supply Current Analog $+V_S$ | Full | VI | | 180 | 240 | | 180 | 240 | mA |
| Supply Current Digital $+V_S$ | Full | VI | | 43 | 80 | | 43 | 80 | mA |
| Supply Voltage $-V_S$ | Full | VI | −4.95 | −5.2 | −5.45 | −4.95 | −5.2 | −5.45 | V |
| Supply Current Analog $-V_S$ | Full | VI | | 210 | 320 | | 210 | 320 | mA |
| Supply Current Digital $-V_S$ | Full | VI | | 65 | 110 | | 65 | 110 | mA |
| Nominal Power Dissipation | Full | VI | | 3.2 | 4.0 | | 3.2 | 4.0 | W |
| PSRR[13, 15] | +25°C | I | | 0.01 | 0.02 | | 0.01 | 0.02 | %/% |

NOTES

[1]Absolute maximum ratings are limiting values, to be applied individually, and beyond which the serviceability of the circuit may be impaired. Functional operation under any of these conditions is not necessarily implied. Exposure to absolute rating conditions for extended periods of time may affect device reliability.

[2]Maximum junction temperature should not be allowed to exceed +175°C. Hybrid thermal model:

$t_{JUNCTION} = t_{AMBIENT} + P_{DISSIPATION} \times (\theta_{CA}) + T_S - T_C)$ max

where $(T_S - T_C)$ max = 10°C

46-lead metal DIP: $\theta_{CA}$ = 14°C/W in still air;

$\theta_{CA}$ = 6°C/W with 500 LFPM air flow.

[3]Determined by 3 dB reduction in reconstructed output.

[4]Input at 1 dB below full scale.

[5]Measured at 10 MHz encode rate.

[6]Measured from ENCODE in to data out for LSB only.

[7]For full-scale step input; 12-bit accuracy is attained in the specified time.

[8]Recovers to 12-bit accuracy in specified time following 200% full-scale input voltage.

[9]Excludes pipeline delay of two clock cycles (see timing diagram).

[10]Worst case spurious in-band signal relative to input level.

[11]RMS signal to RMS noise, including harmonics.

[12]Worst case spurious in-band signal relative to level of input tones, which are both −7 dB below full scale.

[13]Sensitivity of full-scale gain error with respect to power supply variation within supply Min/Max limits.

[14]ENCODE signal rise and fall times should be less than 5 ns for normal operation. Transition from "0" to "1" initiates conversion.

[15]PSRR is tested over given voltage range.

Specifications subject to change without notice.

**EXPLANATION OF TEST LEVELS**

**Test Level**

I – 100% production tested.

II – 100% production tested at +25°C, and sample tested at specified temperatures.

III – Periodically sample tested only.

IV – Parameter is guaranteed by design and characterization testing.

V – Parameter is a typical value only.

VI – All devices are 100% production tested at +25°C. 100% production tested at temperature extremes for military temperature devices. Guaranteed, not tested, for commercial temperature range

**ORDERING GUIDE**

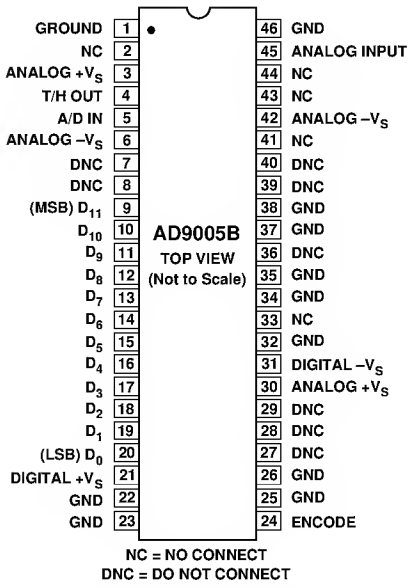
| Model | Temperature Range | Package Description | Package Option* |
|---|---|---|---|
| AD9005BKM | 0°C to +70°C | 46-Lead DIP, Commercial Temperature | M-46 |
| AD9005BTM | −55°C to + 125°C | 46-Lead DIP, Military Temperature | M-46 |
| AD9005/PCB | 0°C to +70°C | AD9005 Evaluation Board | |

*M = Hermetic Metal Can DIP.

## OUTPUT CODING

| ANALOG INPUT | $D_{11}$ | $D_{10}$ | $D_9$ | $D_8$ | $D_7$ | $D_6$ | $D_5$ | $D_4$ | $D_3$ | $D_2$ | $D_1$ | $D_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ≥+1.024 V | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ≤1.024 V | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## PIN DESIGNATIONS




NC = NO CONNECT
DNC = DO NOT CONNECT

## PIN FUNCTION DESCRIPTIONS

| Pin | Name | Description |
|---|---|---|
| 1 | GROUND | Circuit ground. All grounds should be connected together near the AD9005B. |
| 2 | NC | Not internally connected. |
| 3 | ANALOG $+V_S$ | Positive analog supply pin. Nominally +5 V dc. |
| 4 | T/H OUT | Output of internal track-and-hold amplifier. Connect to Pin 5 for normal operation. |
| 5 | A/D IN | Input to internal A/D encoder. Connect to Pin 4 for normal operation. |
| 6 | ANALOG $-V_S$ | Negative analog supply pin. Nominally –5.2 V dc. |
| 7, 8 | DNC | Do not connect. Internal test point. |
| 9 | $D_{11}$ (MSB) | Most significant bit of digital output data. |
| 10–19 | $D_{10}$–$D_1$ | Digital data outputs. |
| 20 | $D_0$ (LSB) | Least significant bit of digital output data. |
| 21 | DIGITAL $+V_S$ | Positive digital supply pin. Nominally +5 V dc. |
| 22, 23 | GROUND | Circuit ground. All grounds should be connected together near the AD9005B. |
| 24 | ENCODE | Convert command. TTL compatible, rising edge triggered. |
| 25, 26 | GROUND | Circuit ground. All grounds should be connected together near the AD9005B. |
| 27–29 | DNC | Do not connect. Internal test point. |
| 30 | ANALOG $+V_S$ | Positive analog supply pin. Nominally +5 V dc. |
| 31 | DIGITAL $-V_S$ | Negative digital supply pin. Nominally –5.2 V dc. |
| 32 | GROUND | Circuit ground. All grounds should be connected together near the AD9005B. |
| 33 | NC | Not internally connected. |
| 34, 35 | GROUND | Circuit ground. All grounds should be connected together near the AD9005B. |
| 36 | DNC | Do not connect. Internal test point. |
| 37, 38 | GROUND | Circuit ground. All grounds should be connected together near the AD9005B. |
| 39, 40 | DNC | Do not connect. Internal test point. |
| 41 | NC | Not internally connected. |
| 42 | ANALOG $-V_S$ | Negative analog supply pin. Nominally 5.2 V dc. |
| 43 | NC | Not internally connected. |
| 44 | NC | Not internally connected. |
| 45 | ANALOG INPUT | Analog input. Full scale of + 1.024 V. |
| 46 | GROUND | Circuit ground. All grounds should be connected together near the AD9005B. |

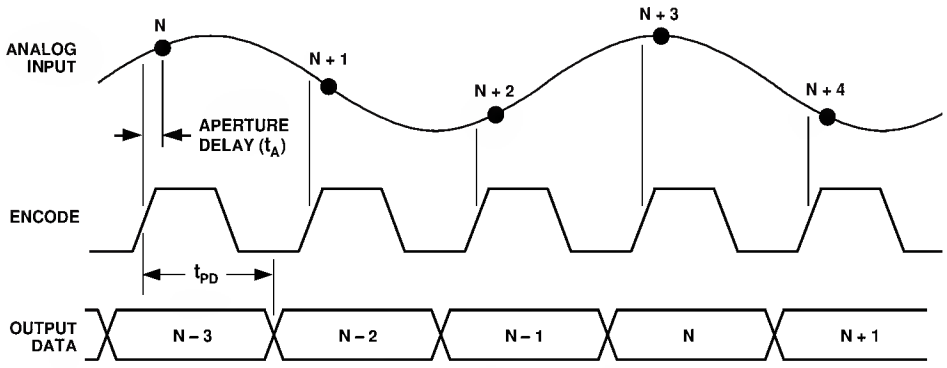



*Figure 1. Timing Diagram*

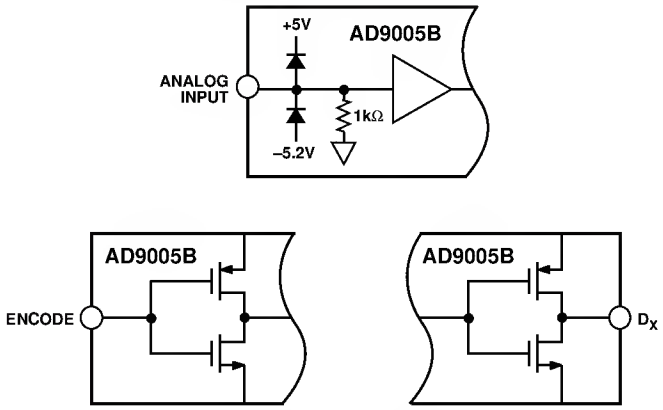



*Figure 2. Equivalent Input/Output Circuits*

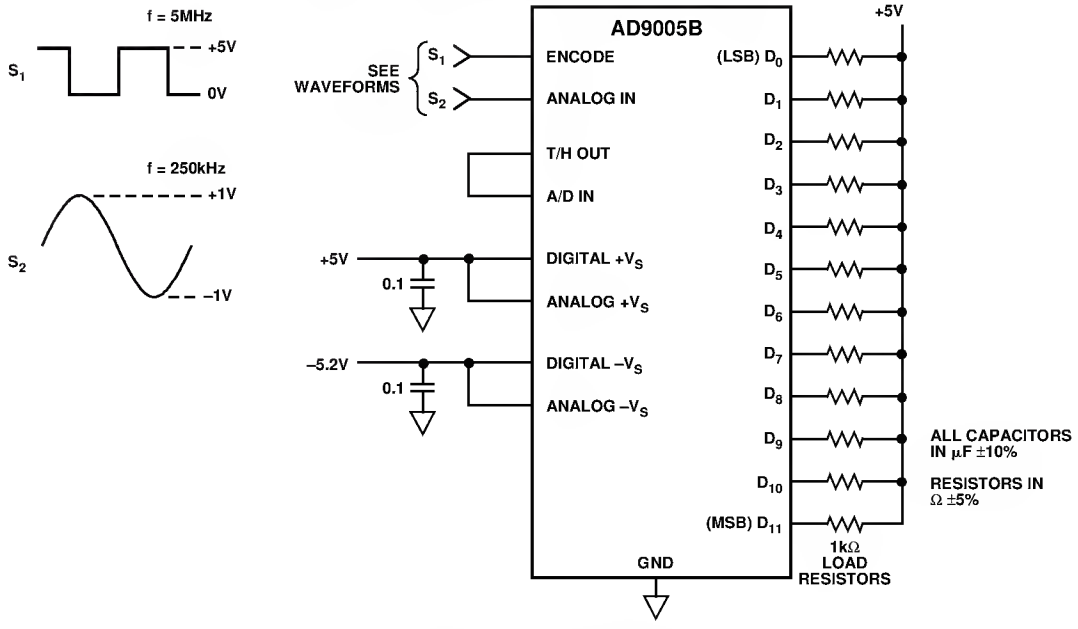



*Figure 3. Burn-In Circuit*

## APPLICATIONS INFORMATION

The AD9005B is a complete analog-to-digital converter. The AD9005B uses a subranging A/D architecture enhanced by hybrid technology. This includes an on-board track-and-hold amplifier, on-board references, timing circuitry and output latches.

The analog input of the AD9005B is fed directly into the internal track-and-hold amplifier, thus eliminating the need for external signal conditioning in many applications. This amplifier provides low input capacitance and a bipolar (±1.024 V) input range. Normally reverse-biased Schottky diodes on the input provide overrange protection. If the amplitude, bandwidth or dc voltage level of the analog input signal calls for external signal conditioning, it is advisable to use an amplifier with low harmonic distortion and low noise characteristics. Selecting the amplifier may be difficult because the performance of the AD9005B will probably exceed the performance of most commercially available amplifiers. A notable exception is the AD9617, a wideband low noise current feedback amplifier. It is important to remember that band limiting the analog input signal can avoid aliasing during the A/D conversion process.

Timing in the AD9005B is critical, and careful measures must be taken to support 12-bit accuracy. One simple way to enhance the performance of the AD9005B is to synchronize the system clock to a crystal oscillator. This will minimize any clock jitter, a must for maintaining the spectral purity of analog signals near Nyquist limits. Because the conversion cycle begins with the rising edge of the encode signal, a fast, clean, rising edge will also help to reduce any clock jitter.

When the ENCODE signal of the AD9005B goes HIGH, the internal track-and-hold enters the hold state; after 65 ns, it returns to track mode. In applications in which the AD9005B is slowly or intermittently clocked (i.e., in burst mode), the encode signal should be returned to a logic LOW state during the idle periods.

The ENCODE signal pulse width should also be adjusted so it is in the HIGH (hold) state for a minimum of 25 ns. This ensures that the T/H enters the hold mode before the A/D conversion takes place.

The AD9005B has many appealing characteristics for 12-bit A/D converter applications. Its dynamic performance is state-of-the art in hybrid technology. Typical applications include radar, missile guidance, digital oscilloscopes, waveform analyzers, medical instrumentation, electro-optics, communications and ESM.

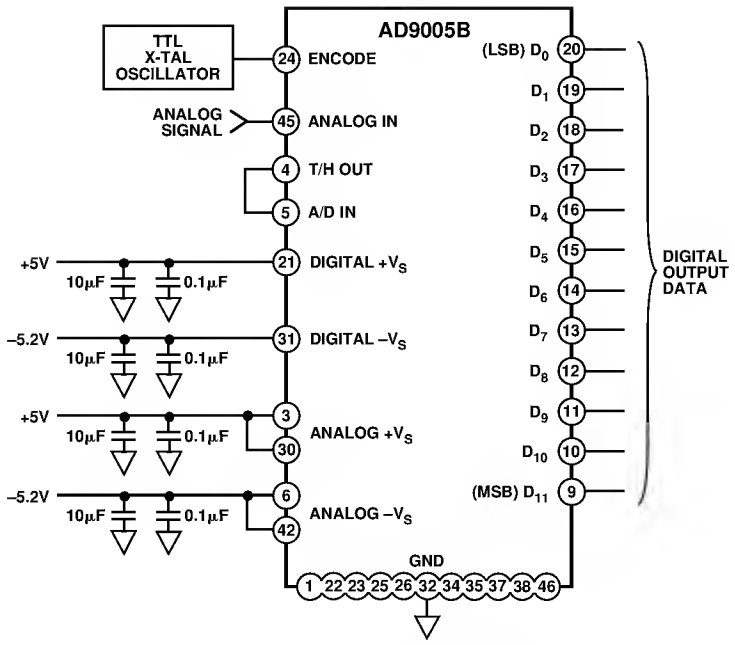



*Figure 4. Typical Application*

**Layout Information**

The accuracy of a 12-bit converter, especially one with the dynamic performance level of the AD9005B, requires that designers pay careful attention to printed circuit board layouts. Analog signal paths should be impedance matched, with termination/load resistors at or near package connections. Analog signal paths should also be isolated from digital signal paths. Otherwise digital signals can be capacitively coupled into the analog section of the circuit, degrading the overall performance of the A/D converter.

Digital switching noise on power supplies can also degrade converter performance. Because of this noise (inherent with TTL logic), the digital power supplies of the AD9005B should be separated from the analog power supplies. In addition, each power supply should be capacitively decoupled to ground. To accomplish this, a single large value capacitor with a high resonant frequency (a 10 µF tantalum capacitor for example) should be used on each of the AD9005B's power supplies, at or near the package. In addition, a lower value capacitor with good high frequency characteristics (a 0.1 µF ceramic chip capacitor is recommended) should be connected to each power supply pin connection.

For applications in which only single +5 V and/or –5.2 V supplies are available, a ferrite bead, placed in series between the analog and digital power pins, can be used to isolate the digital noise from the analog circuits.

Noise on the circuit ground is often the limiting factor in A/D converter performance. Perhaps the most critical concerns of circuit layout are the ground connections. To reduce ground noise, a two-sided printed circuit board is recommended, the component side being reserved (as much as possible) for a single, low impedance ground plane. The other side should be used for all (possible) power and signal connections. Each of the ground connections of the AD9005B should be connected to the ground plane, and most of the area under the AD9005B should be part of this ground plane. The metal case of the AD9005B is connected to ground.

Operation of the AD9005B requires that Pin 4, the output of the internal track-and-hold, be connected to Pin 5, the input to the AD9005B's A/D converter circuitry. A suggested layout, illustrating this connection, is shown below.

A final suggestion regarding circuit layout concerns the use of sockets. Ideally, parts should be soldered into boards in final designs. If sockets must be used, individual pin sockets are recommended to avoid lead inductance and capacitive coupling between adjacent pins. Pin sockets are available from Amp, part #6-330808-0.

**SUGGESTED LAYOUT**

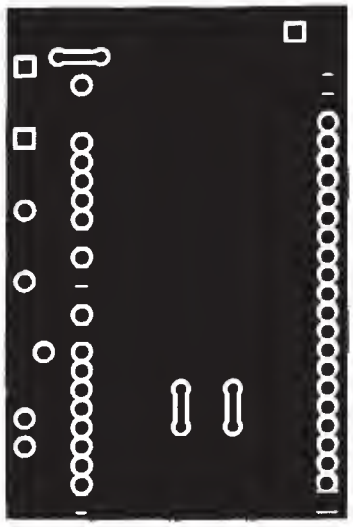


*Figure 5. GND Plane Side (As Viewed from Top)*

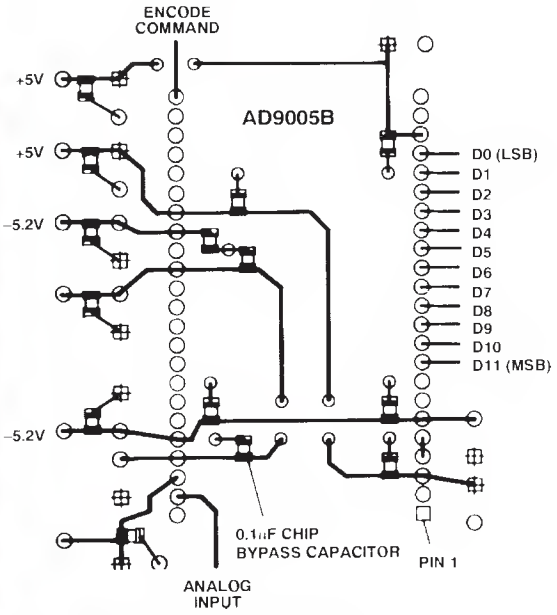



*Figure 6. Solder Side (As Viewed from Top)*

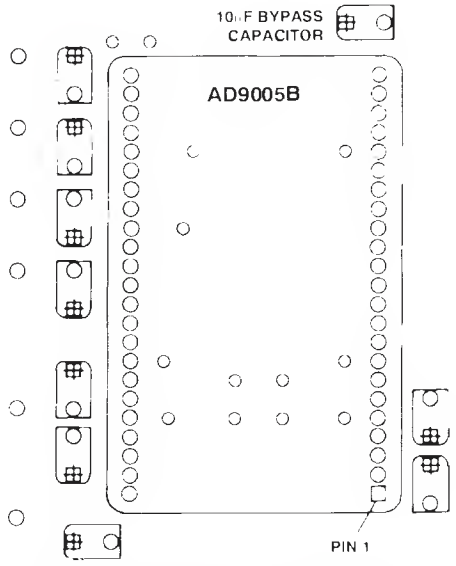



*Figure 7. Component Mounting (As Viewed from Top)*

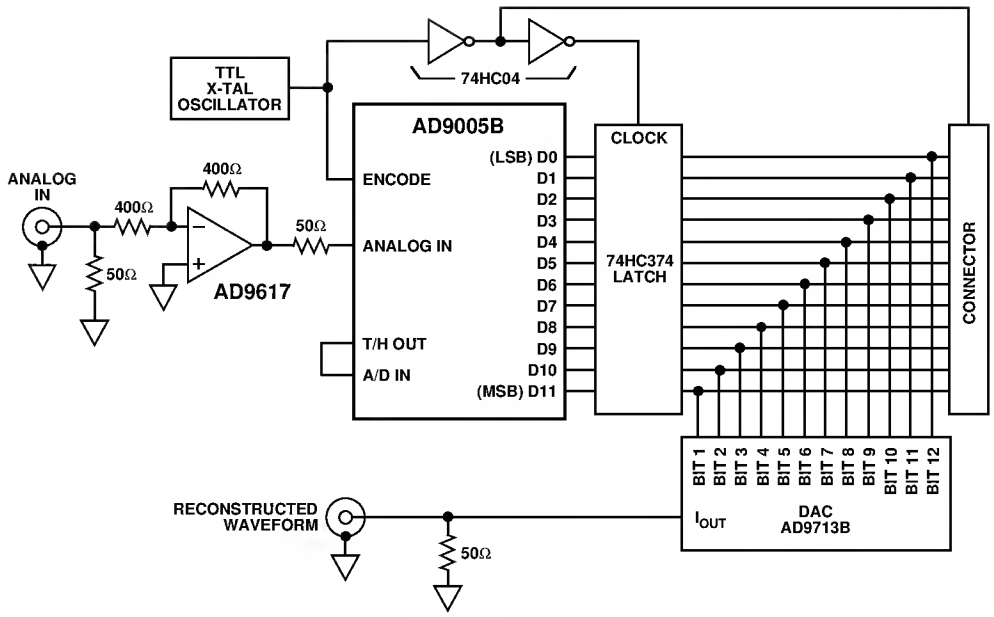



*Figure 8. Evaluation Circuit*

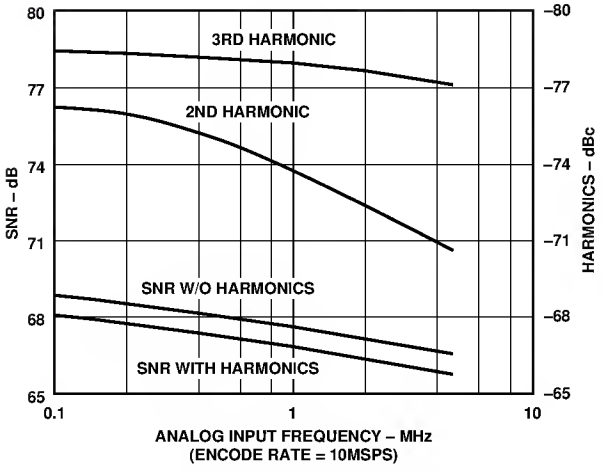
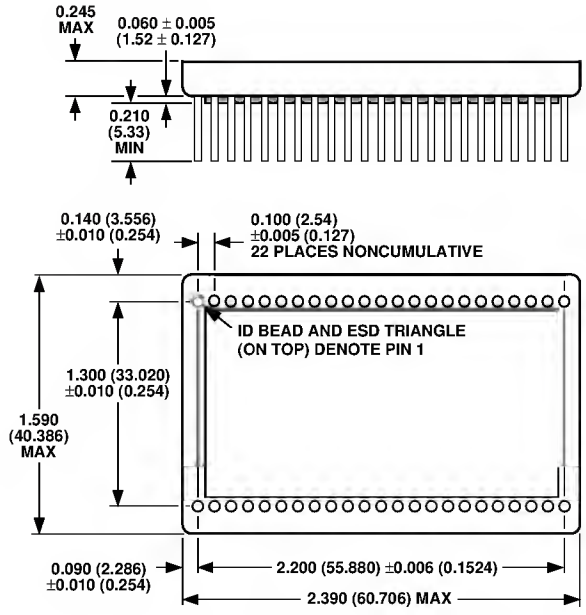



*Figure 9. Dynamic Performance (@ +25°C)*

## OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

### 46-Lead Metal Dual In-Line Can




C1874a–1–5/97

PRINTED IN U.S.A.